“Strategies to reduce enteric methane emissions from beef cattle”

Dr Stuart Kirwan

Teagasc Grange
Animal and Bioscience Research Department

Estonian Beef Breeders Conference
12th October, 2023

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Euroopa Liit maaelu arenguks

Euroopa Maaelu Arengu Põllumajandusfond: Euroopa investeeringud maapiirkondadesse

Introduction

- **Methane** is a potent greenhouse gas (GHG)
- **Agriculture** is responsible for 37% of Ireland's GHG emissions
- **Methane** accounts for ~70% of Irish Agri-GHG emissions (EPA, 2022)
  - ➢ Enteric fermentation (feed digestion) **62%**
  - ➢ Stored slurries and manures **8%**
- **Ireland: Climate Action and Low Carbon Development Bill 2021**
  - ➢ 25% reduction in Agri-emissions by 2030
  - ➢ 10% reduction in ruminant derived methane


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Irish government agrees landmark 25% reduction in agriculture emissions by end of decade

- The target for industry will be 35pc under the plan
- The target for commercial buildings is to be 45pc reduction in emissions and 40pc for residential buildings.


FW LATEST KNOW HOW MARKETS DISCOVER 18° Sutton

Irish farmers face 'devastating blow' of 25% emissions cut

Philip Case
30 July 2022

Farmers in the Republic of Ireland will be asked to reduce their greenhouse gas emissions by 25% by 2030.

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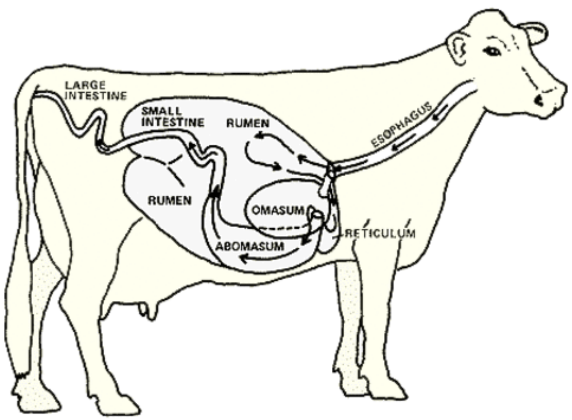
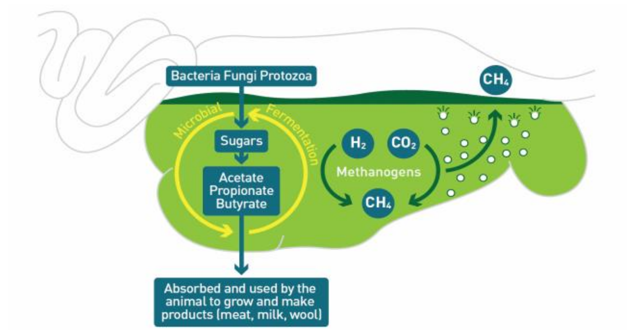
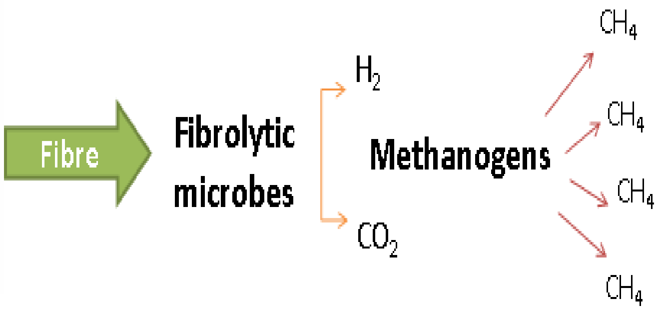
Ruminants

Ruminants - unique in their ability to convert cellulose in plant cell walls into high quality meat and milk protein for humans





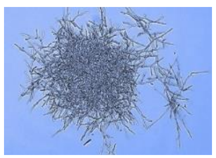


Bacteria

10^{10} to 10^{11} cells/ml

Anaerobic Fungi

<10^5 cells/ml

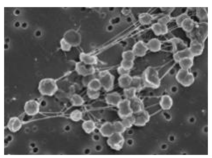


Ciliate Protozoa

<10^5 cells/ml

Methanogenic Archaea

10^6 to 10^8 cells/ml



Viruses

10 phage for every bacteria

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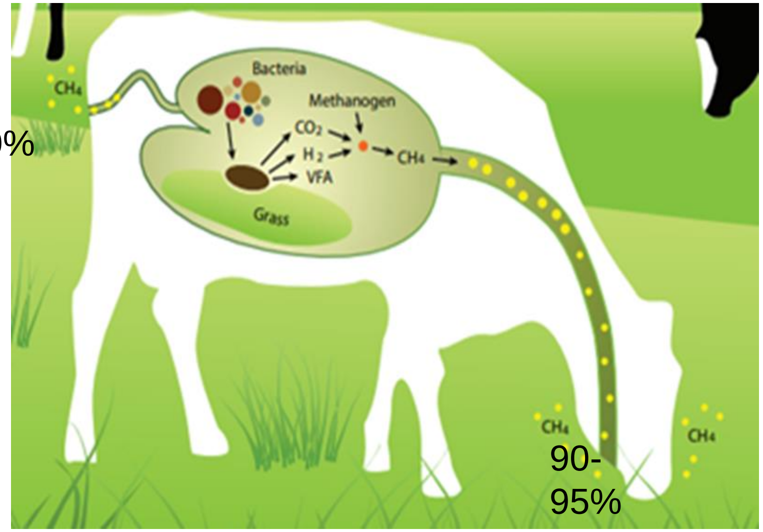
Enteric methane emissions

- 2nd most important GHG implicated in global warming
- $GWP_{100} = 28$
- Atmospheric half life 9-12 years
- Enteric methane from ruminant livestock production accountable for:
  - ~60% of Irish agricultural GHG emissions
  - 8-10 % from manure



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Measuring Enteric Methane Output

Respiration chamber

SF_6 tracer

GreenFeed system

Reporting methane output:

- Daily methane output (CH_4 g/ day)
- Methane yield (CH_4 g/ kg of DMI)
- Methane intensity (CH_4 g/ kg of carcass weight)

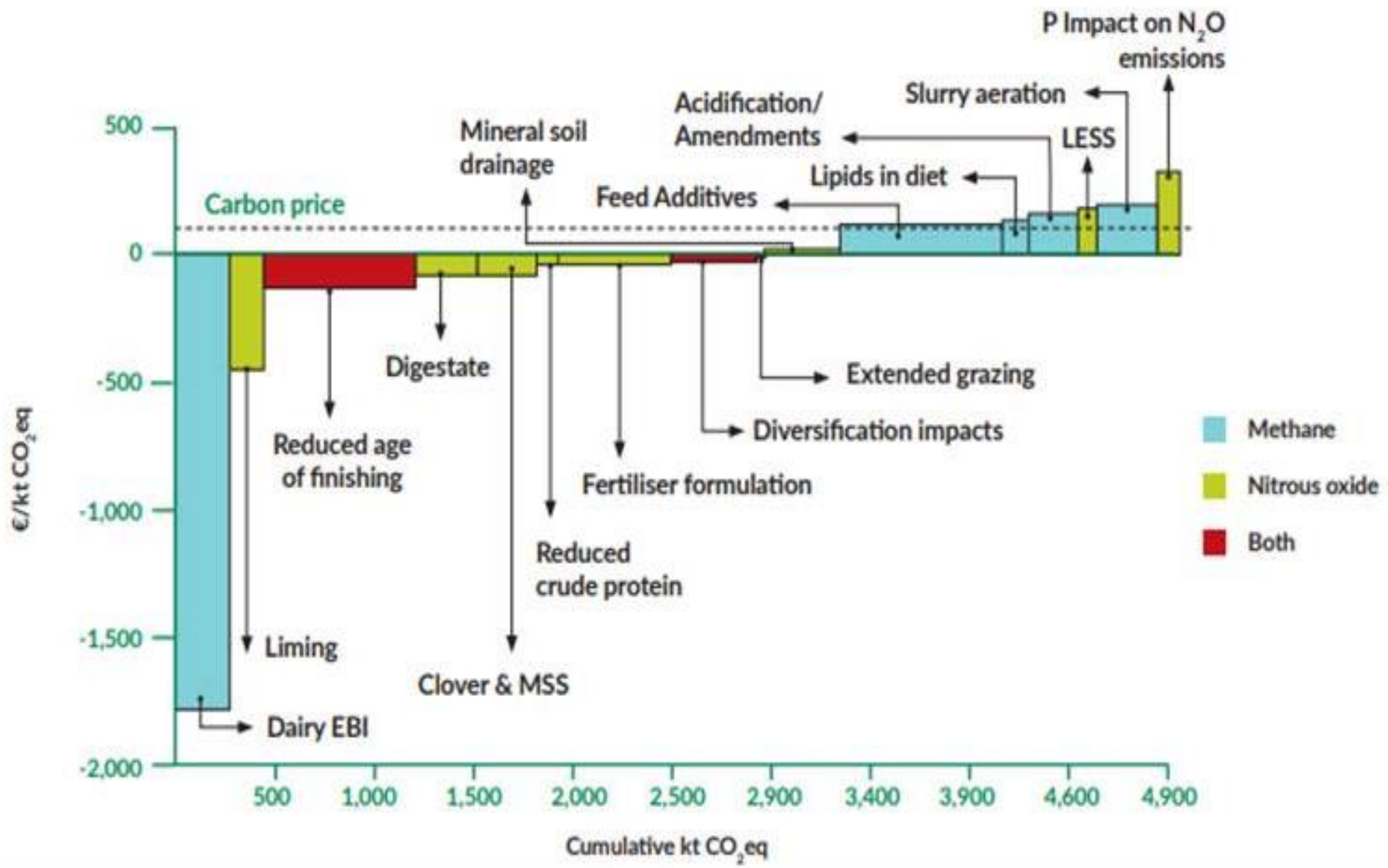
- Improved management practices – Farm efficiency
- **Teagasc MACC**
    - **Reducing age of slaughter**

- **Grassland management**
    - Significantly lower methane in pasture based settings

- **Breeding strategies** (Teagasc and ICBF)
    - Enhance feed efficiency and lower methane
    - Longer term strategy

- **Feed additives**
    - Can they be delivered during grazing?

Marginal Cost Abatement Curve (MACC)



Food Vision Beef Group – Proposed Measures

Measure	GHG reduction (Mt CO_2e)
1. Improve live weight with earlier slaughter	**0.57 – 0.82**
2. Earlier age at first calving	0.05 – 0.10
3. Feed additives to mitigate methane	**0.15 – 0.30**
4. Replace 90% of CAN with Protected Urea	0.2
5. Reduce inorganic N use by 27-30%	0.26
6. Increase area in organic production to 180,000 ha	0.2
7. Breeding strategies – carbon sub-index and efficiency traits	**0.1 - 0.3**

FV Beef Group, **1.5 - 2.2** Mt CO_2e

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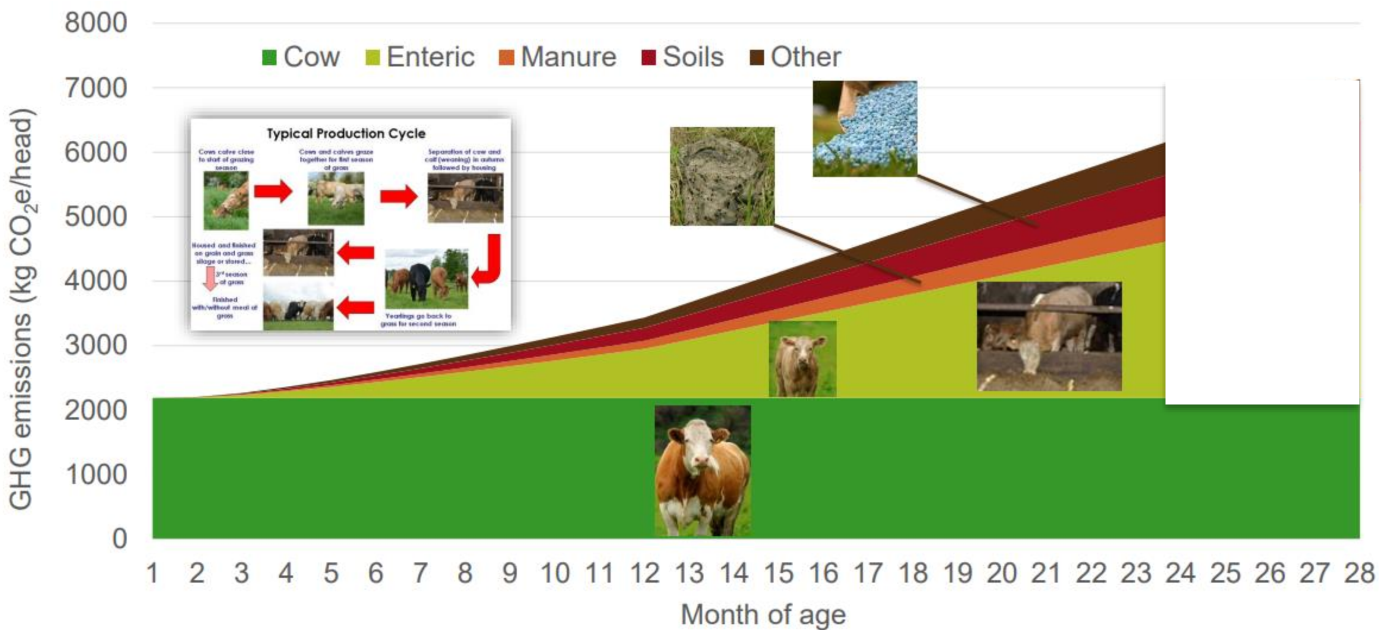
Reducing finishing age



P. Crosson, 2022

Reducing finishing age improves €€€

Table 3
Economic results (€/ha) of suckler beef steer-heifer production systems investigated by the Grange Beef Systems Model (GBSM).

	Scenario[a]												
	BASE	HCR	LCR	ECD	LCD	HRR	LRR	HADG	LADG	EF	LF	HIGH	LOW
Gross output value	1460	1627	1294	1478	1446	1469	1451	1570	1351	1355	1674	1738	1343
Concentrate feed	264	292	236	270	267	264	264	299	247	181	200	306	132
Grassland	181	207	157	189	170	181	181	206	158	161	383	207	229
Machinery hire	37	40	35	37	40	37	37	37	37	32	41	36	39
Silage making	142	149	136	138	154	142	142	146	138	132	186	139	176
Other[b]	127	131	123	126	129	128	127	127	127	127	139	129	135
Total variable costs	752	819	687	758	759	752	752	815	707	634	948	817	712
Gross margin	708	807	606	720	686	716	700	755	644	721	726	920	632
Total fixed costs	444	461	426	438	444	444	443	445	442	398	524	422	452
Net margin	264	346	180	282	242	272	257	309	203	323	253	498	180
COP/kg carcass (€)[c]	3.75	3.61	3.92	3.69	3.88	3.68	3.81	3.68	3.87	3.53	3.97	3.30	3.96

Scenario	Steers (mo)	Heifers (mo)
BASE	24	24
Early finishing (EF)	22	20
Late Finishing (LF)	30	28

Taylor et al., 2020

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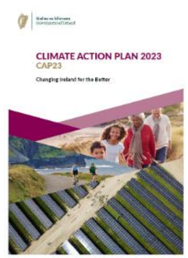
Finishing age target - 2030

Direct Impact measures to mitigate Greenhouse Gas Emissions from the beef sector				
Measure	**Estimated CO_2 equivalent reduction**	**Estimated economic cost at farm level**	**Target GHG**	**Timeframe**
1. Improving live weight performance for beef cattle resulting in earlier slaughter ages, reducing age of slaughter by between 2.7 and 3.9 months on average, from 2018 average of 26 months to 22-23 months on average by 2030.	0.57 – 0.82 Mt CO_2 eq	Estimated to have a positive economic effect at farm level with some potential loss in tonnage for the processing sector. Farm-level investment in weight recording and improvement in farm management practices are required	Methane	Short/Medium

	2018	2022	Scenario	
All	26.0	25.6	23.2	22.1
Steers	27.9	26.8	24.6	23.7
Heifers	26.0	25.6	23.4	21.0
Bulls	19.4	19.1	16.7	16.2



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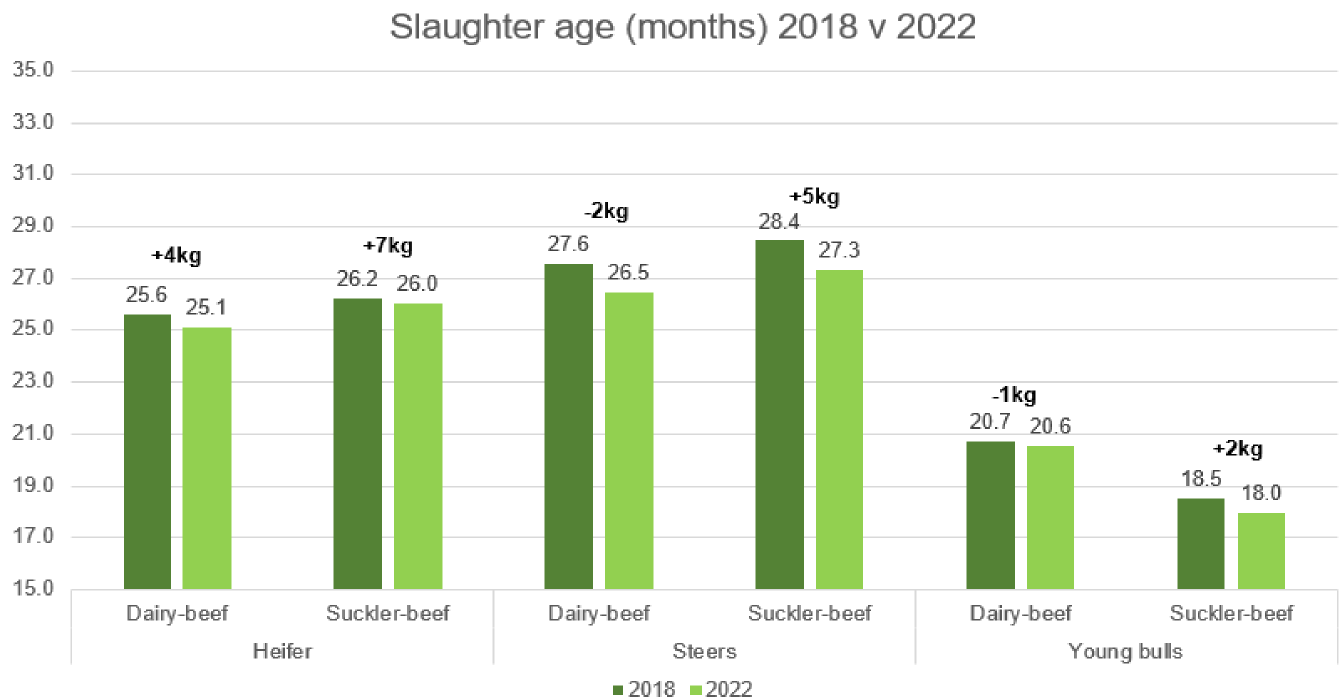
Current progress: finishing age

	2018		2022	
	#	Age (months)	#	Age (months)
Heifers	455225	26.0	479255	25.6
Steers	629128	27.9	676431	26.8
Bulls	185006	19.4	125836	19.1
Total	1269359	**26.0**	1281522	**25.6**



Mean slaughter age ↓ 12d

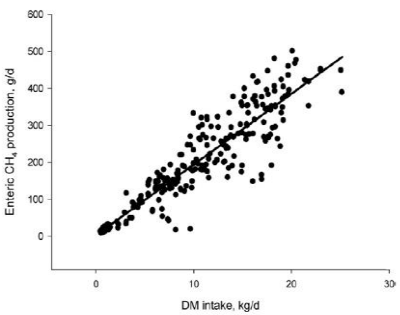
Heifers slaughter age ↓ 12d

Steers slaughter age ↓ 34d

Bulls slaughter age ↓ 10d

Animal breeding as a mitigation strategy

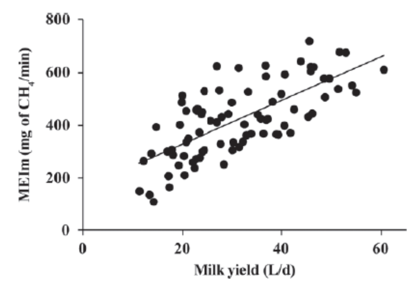
- **Benefits**
  - Methane output is heritable: h^2 of 0.19-0.30 (Donoghue et al., 2016)
  - Permanent and cumulative reductions
  - High mitigation potential for livestock systems unsuited to daily mitigation supplementation
- **Limitations**



(Hristov et al., 2013)

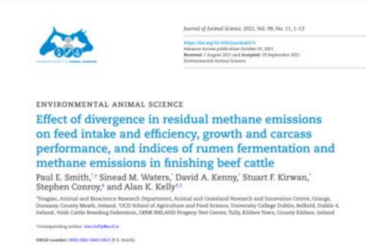
Traits[1]	DME
DMI, kg	0.50***
Average daily gain, kg	0.31***
Carcass weight, kg	0.31***
Muscle depth, mm	0.13*
Fat depth, mm	0.14*
Intramuscular fat, %	0.03
G:F	−0.05
RFI	0.23***

(Smith et al., 2021)



(Garnsworthy et al. 2012)

Residual methane emissions


Journal of Animal Science, 2021, Vol. 99, No. 11, 1–13

ENVIRONMENTAL ANIMAL SCIENCE

Effect of divergence in residual methane emissions on feed intake and efficiency, growth and carcass performance, and indices of rumen fermentation and methane emissions in finishing beef cattle

Paul E. Smith, Sinead M. Waters, David A. Kenny, Stuart F. Kirwan, Stephen Conroy, and Alan K. Kelly

- Residual methane (RME) offers a more balanced approach to identify an animal's true physiological methane potential
  - Difference between an animal's predicted, based on DMI and bodyweight, and actual level of methane output
  - Similar concept to residual feed intake (RFI)
  - Helps negate influence of DMI and BW on methane output
- RME strongly correlated with daily CH_4 (g/day) but independent of DMI and BW (Bird-Gardiner et al., 2017)
- No genetic correlation of RME with DMI or BW (Manzanilla-Pech et al., 2016)
- Relationship with animal productivity?

ICBF Progeny Performance Test Centre

- Irish Cattle Breeding Federation (ICBF)
  - Non-profit organisation in charge of the recording and processing of all data in Irish cattle breeding
- ICBF Progeny Performance Test Centre in Tully Co. Kildare
  - Performance test >600 beef cattle per year as part of national bull evaluation programme
  - Various breeds and sires
- Cattle undergo minimum 100 day finishing period
  - Steers and heifers fed TMR (75% concentrates, 25% hay)
  - 30 day acclimatisation period
  - +70 day feed efficiency period
  - Measure feed intake (RIC), FCR, ADG, meat quality, fat scoring, carcass weight, KO%
  - Slaughtered in a commercial abattoir (approx. 1 hour drive from Tully)
- Enteric methane emissions estimated with GreenFeed system
  - 4 weeks of “training” followed by 21 days measurement period
  - 11-30 animals/GreenFeed

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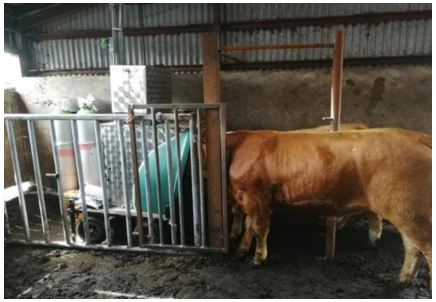

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RME ranking and animal productivity

Production	High	Medium	Low	P-value
DMI (kg)	10.56	10.29	10.26	0.2829
ADG (kg)	1.42	1.38	1.34	0.1678
Initial Weight (kg)	472.9	477.43	473.16	0.8195
MetBW (kg)	111.22	111.52	110.73	0.8327
Final Weight (kg)	599.04	598.81	592.21	0.7022
Carcass Weight (kg)	328.22	334.71	331.82	0.4563
FCR	7.49	7.68	7.91	0.1257
RFI	0.16	0.03	0.1	0.4799

RME ranking and methane output

Methane	High	Medium	Low	P-value
DMI (kg)	10.67	10.45	10.51	0.5862
Weight (kg)	512.81	516.17	512.08	0.8707
DME (g/day)	264.97[a]	224.03[b]	184.39[c]	<.0001
CO_2 (kg/day)	8.75[a]	8.29[b]	8.07[c]	<.0001
RME (g/day)	37.95[a]	-0.11[b]	-40.34[c]	<.0001
MY (g/ kg DMI)	25.19[a]	21.60[b]	17.70[c]	<.0001
MADG (g/ kg ADG)	191.26[a]	167.09[b]	144.06[c]	<.0001
MI (g/ kg CW)	0.81[a]	0.67[b]	0.57[c]	<.0001

→ 30.4% difference (DME)

→ 29.6% difference (MI)

- RME explained 45% of the variation in daily methane production

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ICBF publishes world-first methane data for breeding bulls

The move towards selecting bulls based on their progeny's methane output has begun with the publication of a new database.

Caitríona Morrissey

BEEF > NEWS

21 April 2023

ICBF test evaluations for Gross Methane genomic predicted transmitting abilities

Methane PTAs are provided for All AI Bulls - Beef & Dairy

1,525 Tully cattle with methane phenotypes and 3,348 animals with feed intake phenotypes were used in this evaluation.

The most desirable PTAs are negative indicating the progeny will emit less methane. The trait is measured in grams per day

The data has been collected at the Tully beef performance research centre

Tag	Name	Main Breed	Birth Year	Owner	Active	Methane Gebv	Direction of PTA relative to average sire	Methane Reliability %	Num Progeny in eval	Avg Num records per progeny	Avg Age progeny	Avg Methane of Progeny
CH4321	LAPON	CH	2015	NATIONAL CATTLE BREEDING CNTR	y	-5.76	Favourable	81	27	325	561	237
AA4375	CARRIGROE NATIONWIDE 1450	AA	2016	NATIONAL CATTLE BREEDING CNTR		7.03	Unfavourable	81	20	241	528	258
LM4565	KILMAGEMOGUE LEO	LM	2016	GENEIRELAND MATERNAL PROGR		-5.52	Favourable	80	20	309	514	248
CH2000	COOM INDURAIN	CH	2013	DOVEA GENETICS		10.03	Unfavourable	77	19	241	534	240
LM4360	AHERLA K 7 P	LM	2015	NATIONAL CATTLE BREEDING CNTR	y	-7.41	Favourable	78	18	228	506	229
CH4252	CAVELANDS LEVI	CH	2015	NATIONAL CATTLE BREEDING CNTR	y	5.3	Unfavourable	76	17	234	505	222
SI2367	BARNATTIN GEORGE 2	SI	2015	GENEIRELAND MATERNAL PROGR		25.61	Unfavourable	78	16	237	486	279

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Methane emissions 5 Star animals

Terminal Index avg euro value	CH_4 g/d	CO_2 g/d	DMI kg	CH_4 g/kg	ADG kg/d	Final LW kg	Carcass wt kg	Carcass Conformation	Age at slaughter (d)	Commercal beef value (€)
5 star	218	9146	11.26	19.58	1.30	647	385	10.66	573	139
140								U=/U-		
4 star	240	9120	11.24	21.94	1.33	657	381	10.358	582	120
119.89								U-/U=		
3 star	248	9359	11.85	21.107	1.39	666	377	9.78	584	94
93.107								R+/U-		
2 star	255	9570	12.43	20.697	1.44	660	362	8.869	577	60
64.7								R=/R+		
1 star	254	9231	12.32	21.51	1.44	644	349	8.218	595	26
								R=		

International reports on feed additives

Dr Roger Hegarty NZAGRC

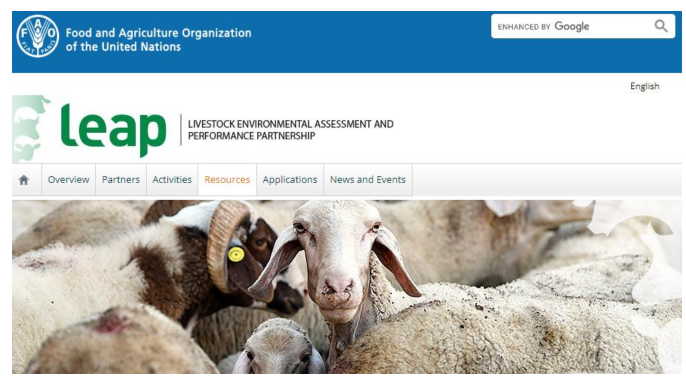
- Only two of the additives evaluated delivered over 20% mitigation
  - **Bovaer** (3-NOP)
  - **Asparagopsis** (red algae)
  - Nitrate (~10% reduction)

Constraints with feed additives:

- 'Insufficient evidence of a **co-benefit** of increased production'
- Rely **on additives mixed into a total mixed ration** – fed continuously
- Extensive or grazing systems?

TAG FAO LEAP Partnership 2022

'*more research is needed to develop, adapt, and evaluate anti-methanogenic strategies for grazing systems' (Beauchemin et al., 2022).*



What do we want from a Feed Additive?

- **Must Have**
  - Consistent methane reduction potential
  - Mechanism of delivery to the animal
  - Capable of counting in the national inventory
  - No food safety/residue implications
  - No negative performance effects and palatability
- **Desirable**
  - Low Cost
  - Increased performance benefits
  - Natural origin
  - Potential for combination with other solutions

‘METH-ABATE’ - Development of novel farm ready technologies to reduce methane emissions from pasture based Irish agricultural systems

- **Feed additives** to mitigate methane emissions – monitoring their effects on animal productivity
  - Bovaer (3-NOP)
  - Seaweeds and seaweed extracts
  - Lipids (e.g., linseed oil, olive feed)
  - Novel oxidising methane inhibitors (RumenGlas)
  - Commercial products (e.g., Agolin, Mootral)

- Formulations for **slow release** options at pasture

- Additives to reduce methane from **stored manure/slurry**

- **Nutritional and toxicological** composition of meat and milk - to confirm **consumer safety – no residues**

- **Life Cycle** (LC) Analysis and **farm level cost effectiveness**

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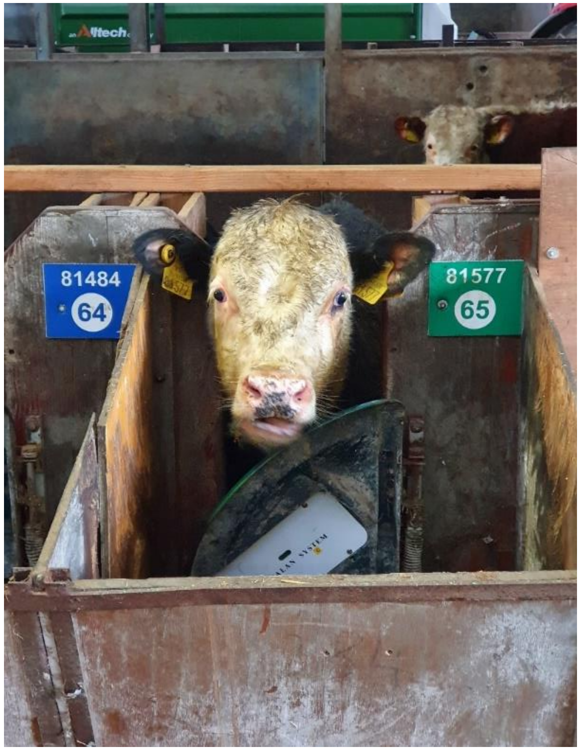
Ollscoil na hÉireann, Gaillimh
afbi Agri-Food & Biosciences Institute

Bovaer (3-NOP) Beef Trial

- Efficacy of 3-NOP in **growing beef cattle**
  - **EFSA approval**
- Teagasc Grange (Sept 2021- Jan 2022)
- 3-NOP vs control n=34
- Acclimatisation period (4 weeks) +12 wk supplementation, TMR diet
  - 50% forage (silage)
- Dairy/beef cross animals
- Aberdeen Angus & Hereford
  - ≤ 6 months of age at the start of experiment
- DMI, daily methane output, daily live-weight gain
- Rumen fluid – collected on 3 separate occasions
  - NH_3, VFA, microbiome analysis



efsa European Food Safety Authority

DSM BRIGHT SCIENCE. BRIGHTER LIVING.

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Results

The effect of 3-nitrooxypropanol on body weight, ADG and G: F in young growing beef cattle offered a 50: 50 forage: concentrate diet.

	Treatment[1]			*P*-value
	Control	3-NOP	SEM	Treatment
Dry matter intake[2]				
Total DMI kg d^{-1}	6.31	6.19	0.157	0.577
PMR DMI kg d^{-1}	5.86	5.73	0.158	0.579
GreenFeed bait kg d^{-1}	0.46	0.45	0.010	0.615
GreenFeed visits	3.00	2.98	0.055	0.777
Start BW[2], kg	190.0	189.3	5.84	0.667
Final BW[2], kg	308.7	308.2	7.66	0.890
Total weight gained, kg	119.4	118.2	2.93	0.737
ADG, kg	1.42	1.41	0.035	0.737
G:F	0.23	0.23	0.005	0.638

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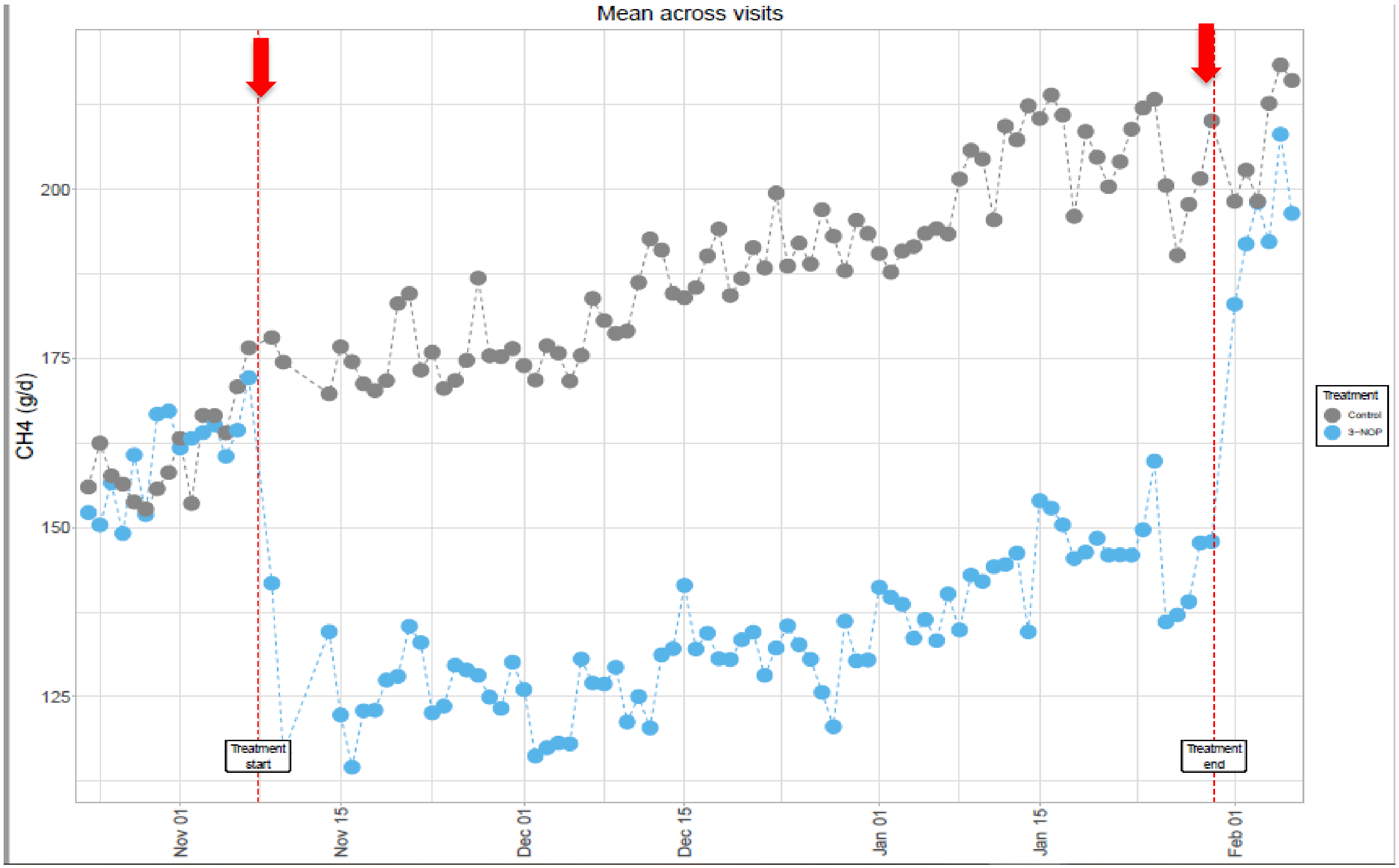
Results

The effect of 3-nitrooxypropanol on gaseous emissions in young growing beef cattle offered a 50:50 forage: concentrate diet.

	Treatment[1]			*P*-value		
	Control	3-NOP	SEM	Treatment	Time-point	Interaction
Gas emissions						
CH_4, g d^{-1}	182.5	126.6	2.36	<0.001	<0.001	<0.001
CH_4, g kg^{-1} total DMI	28.6	20.8	0.381	<0.001	<0.01	0.380
CH_4, g kg^{-1} BW d^{-1}	0.76	0.53	0.010	<0.001	<0.001	0.060
H_2, g d^{-1}	1.12	3.67	0.096	<0.001	<0.001	0.567
H_2, g kg^{-1} total DMI	0.20	0.61	0.025	<0.001	0.858	0.168
CO_2, kg d^{-1}	5.65	5.69	0.056	0.421	0.391	0.203
CO_2, kg kg^{-1} total DMI	0.922	0.943	0.0195	0.423	0.391	0.203

3-NOP on methane



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Effect of feed additives on methane emissions *in vitro* using RUSITEC

	Mmol CH_4/day	*P*-Value
Oxidising inhibitors		
1X UHP	-60%	<.0001
0.5X UHP	-67%	<.0001
Seaweeds/extracts		
Asparagopsis taxiformis[1a]	-41%	0.0078
Asparagopsis taxiformis[1b]	-68%	<.0001
Ascophyllum nodosum[1]	-7%	0.9789
Ascophyllum nodosum[2]	-36%	0.0044
Brown seaweed extract[2]	-15%	0.0217
Feed compound		
Olive feed extract[3]	-26%	0.0317

1 – 1% inclusion rate
2 – 4% inclusion rate
3- 25% inclusion rate

a. harvested in Summer; bromoform = 4.35 mg/g DM
b. harvested in Autumn; bromoform 6.84 mg/g DM

Roskam et al., 2022 In review; O'Donnell et al. In Preparation

Lipids

- Plant oils enriched in PUFA ↓ CH_4
- Mode of action:
  - Inhibition of methanogens and protozoa
  - Alteration of VFA profiles
  - Reduction in feed fermented
  - Biohydrogenation of FA – Sequestering H_2
- Reduction in DMI at inclusion >5%
- 1% ↑ fat = 3.77% ↓ CH_4 g/d
  - 3.3% RSO ↓ CH_4 19% (Brask et al., 2013)
  - 6% SO ↓ CH_4 39% (Jordan et al., 2006)
  - 3.4% LO ↓ CH_4 16% (Boland et al., 2020)

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Effects of offering beef bulls linseed oil, seaweed or a seaweed extract on intake and animal performance

Item	Treatment				SEM	*P*-value
	CON	LSO	SW	EX		
DMI, kg/d	7.14	6.84	7.30	6.92	7.050	0.064
Start weight, kg	380	380	377	377	4.6	0.9254
Mid weight, kg	426	423	426	418	5.4	0.6726
End weight, kg	463	459	463	447	6.1	0.1916
ADG, kg/d	1.09[a]	0.96[ab]	1.06[ab]	0.92[b]	0.045	0.0326
FCR[1]	6.66	7.30	7.07	7.95	0.353	0.0949

[a,b] Means within a row with different superscripts differ significantly (*P*<0.05)

Roskam et al., drafting

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Effects of offering beef bulls linseed oil, seaweed or a seaweed extract on enteric gaseous emissions

	Treatment					
Item	CON	LSO	SW	EX	SEM	*P*-value
CH_4; g/d	208.1[a]	171.2[c]	201.1[ab]	194.4[b]	3.34	<.0001
CH_4; g/kg DMI	29.87[a]	24.93[b]	28.22[a]	27.96[a]	0.573	<.0001
CH_4; g/kg BW	0.498[a]	0.400[c]	0.481[ab]	0.464[b]	0.0091	<.0001
CH_4; g/kg ADG	196.8[ab]	179.2[b]	197.3[ab]	219.2[a]	9.24	0.0236
H_2; g/d	0.535[a]	0.424[b]	0.539[a]	0.500[ab]	0.024	0.0037
CO_2; g/d	6892.8[ab]	6470.0[b]	6911.2[a]	6892.8[ab]	119.37	0.0289

[a,b,c] Means within a row with different superscripts differ significantly ($P<0.05$)

Roskam et al., 2023 drafting

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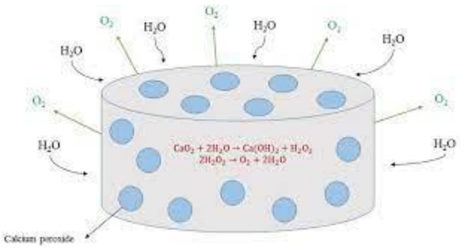
Effect of feed additives on methane emissions in beef cattle

- Compared to unsupplemented control diet:
  - **Brown Seaweed** supplementation tended to ↓ CH_4 g/d (↓**4%**)
  - **Seaweed extract** ↓ CH_4 g/d (↓**7%**), no effect on CH_4 yield or intensity
  - **Linseed oil supplementation:** ↓CH_4 g/d (↓**18**%), CH_4 yield (↓**14%**)
  - **DMI (↓ 5%)** and **ADG (↓17%) reduced** by linseed oil supplementation
  - Residual effects

Roskam et al., drafting

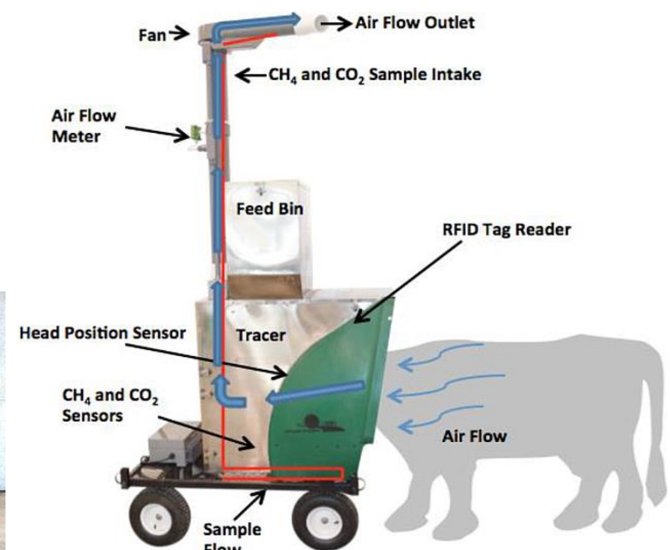
Oxidising methane inhibitors (OMI)



- What are they?
  - Peroxide based compounds
    - Calcium peroxide (CaO_2)
    - Based on the control of rumen oxidation-reduction potential (ORP)
- Mechanism of action
  - 1. Inhibit methanogens
    - ↑ ORP to favourably alter rumen fermentation pathway and suppress methanogenesis
    - Selectively and temporarily inhibiting methanogens
  - 2. Encourage microbial pathways that divert electrons from H_2 and consume H_2 → trap energy in biomass

Effects of CaO_2 in beef cattle

- 72 dairy X bulls
  - » ~16 months old/450kg
  - » 4 dietary treatments (n=18)
  - » 70 day feeding period
    - +7d baseline
    - +7d residual
- Treatments
  - Control (No supplementation)
  - Low (1.35%) (4.35% of ration)
  - High (2.25%) (7.25% of ration)
  - **High pellet (2.25%) (7.25% of ration)**
- Diet
  - 60:40 forage:concetrate
  - Barley based coarse ration with additive included
    - **Fed 2x/d (AM + PM)**
  - 110% of previous days silage intake
  - ~1kg bait feed from GreenFeed



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In vitro screening and development of OMI

- Short-lived reactive oxygen halide species
  - 1X LARS
  - 0.5X LARS
  - 0.25X LARS
  - 1X UHP
  - 0.5X UHP
  - 0.25X UHP
  - 0.5X MgO_2
- Peroxide based compounds
  - CaO2 (RumenGlas)
  - MgO2
    - All assessed at various inclusion rates to ensure no negative effects on digestibility

GlasPort Bio

Most promising *in vitro* results		
	Mmol CH_4/day	*P* Value
Halide species		
1X UHP	-60%	<.0001
0.5X UHP	-67%	<.0001
CaO_2 (RumenGlas)	***-52%***	***<.0001***

- Negative effect on digestibility
- Soluble in water – active may dissolve before reaching animal's rumen

- Controlled, slow release format
- No negative impacts on digestibility
- Insoluble in water – breaks down in rumen

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Sheep experiment – key outcomes

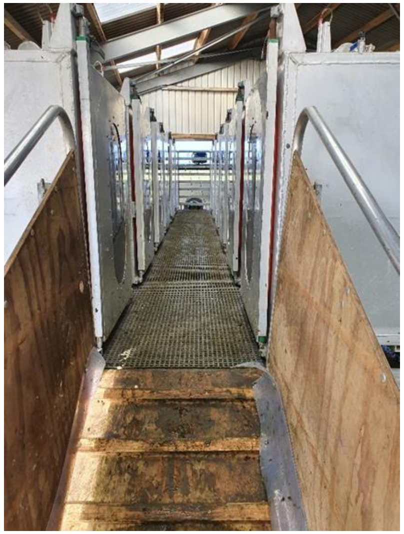
Calcium Peroxide - RumenGlas

- No negative effects on LWG or intakes
- **14% reduction in g CH_4/kg BW**
- **20% increase in ORP** in same treatment

O’Donnell *et al*., In Preparation





Effects of differing inclusion rate and delivery format of CaO_2 on intake, animal performance and ultrasonically measured muscle and back fat depth

	Treatment					
Item	CON	LO	HC	HP	SEM	*P*-value
DMI, kg/d	9.27[a]	9.73[a]	8.23[b]	9.17[a]	0.206	<.0001
Start weight, kg	476	477	472	473	3.4	0.65
Mid weight, kg	514	521	518	516	3.7	0.51
End weight, kg	556	564	550	553	5.0	0.1615
ADG, kg/d	1.32	1.41	1.30	1.30	0.060	0.4836
FCR[1]	7.14	7.13	6.56	7.15	0.281	0.3554
Ultrasound measurements (mm)						
Lumbar fat	2.99	2.95	2.80	3.02	0.106	0.47
Rump fat	3.99	3.95	4.38	3.62	0.222	0.12
Muscle depth	55.0	56.5	54.0	55.8	0.77	0.14

[a,b] Means within a row with different superscripts differ significantly (P<0.05)

[1] kg of DM/kg of gain

Roskam et al., in prep

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Effects of differing inclusion rate and delivery format of CaO_2 on enteric gaseous emissions

	Treatment					
Item	CON	LO	HC	HP	SEM	*P*-value
CH_4; g/d	238.3[a]	197.7[b]	171.3[c]	172.8[c]	3.25	<.0001
CH_4; g/kg DMI	26.08[a]	20.70[b]	20.84[b]	18.99[b]	0.583	<.0001
CH_4; g/kg BW	0.467[a]	0.383[b]	0.332[c]	0.336[c]	0.0062	<.0001
CH_4; g/kg ADG	182.6[a]	145.7[b]	133.1[b]	135.6[b]	5.76	<.0001
H_2; g/d	0.590[a]	0.380[b]	0.382[b]	0.404[b]	0.0176	<.0001
CO_2; g/d	8231.8[a]	7895.8[ab]	7309.0[c]	7664.4[bc]	147.35	0.0003

[a,b,c] Means within a row with different superscripts differ significantly (P<0.05)

Roskam et al., 2022 In review

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Effects of differing inclusion rate and delivery format of CaO_2 on rumen fermentation parameters

	Treatment					Day			*P* value	
Item	CON	LO	HC	HP	SEM	D32	D73	SEM	Trt	Day
pH	6.89[a]	7.14[b]	7.17[b]	7.12[b]	0.044	7.06	7.10	0.030	<.0001	0.27
NH_3-N, mg/L	98.04[a]	81.57[b]	77.96[b]	70.90[b]	4.986	96.40	67.84	3.400	0.01	<.0001
Lactic acid	0.185	0.160	0.221	0.158	0.0176	0.190	0.172	0.012	0.05	0.30
TVFA m*M*	118.93[a]	99.15[b]	93.26[b]	105.26[ab]	4.881	115.63	92.67	3.344	0.01	<.0001
Acetate	75.95	74.94	72.94	74.58	0.983	76.76	72.45	0.673	0.19	<.0001
Propionate	12.94[a]	15.71[b]	19.13[c]	16.88[bc]	0.672	15.58	16.75	0.461	<.0001	0.08
Butyrate	10.99[a]	8.58[b]	7.70[bc]	7.21[c]	0.330	7.47	9.80	0.226	<.0001	<.0001
Valerate	1.00	1.08	1.14	1.21	0.059	1.23	1.00	0.041	0.08	<.0001
A:P ratio	8.53[a]	5.40[ab]	4.56[b]	7.97[ab]	0.979	8.59	4.64	0.671	0.01	<.0001

[a,b,c] Means within a row with different superscripts differ significantly ($P<0.05$)

Roskam et al., 2022 In review

Effects of differing inclusion rate and delivery format of CaO_2 on animal performance and diet digestibility

	Treatment					
Item	CON	LO	HC	HP	SEM	*P*-value
DMI, kg/d	8.37	8.00	7.97	8.02	0.374	0.855
BW, kg	568	572	566	569	6.5	0.932
DMI/kg BW	0.015	0.014	0.014	0.014	0.0664	0.841
Faeces, kg/d	1.84	2.13	2.10	2.16	0.128	0.311
Faecal Ca, %	2.96[a]	4.61[b]	5.41[c]	5.67[c]	0.116	<.0001
DM Digestibility, %						
Dry matter	78.12[a]	73.44[b]	73.63[b]	72.99[b]	0.667	0.001
Organic matter	80.41[a]	76.99[b]	77.71[b]	77.28[b]	0.615	0.008
NDF	75.88[a]	71.89[ab]	72.00[ab]	69.68[b]	0.949	0.006

[a,b] Means within a row with different superscripts differ significantly (*P*<0.05)

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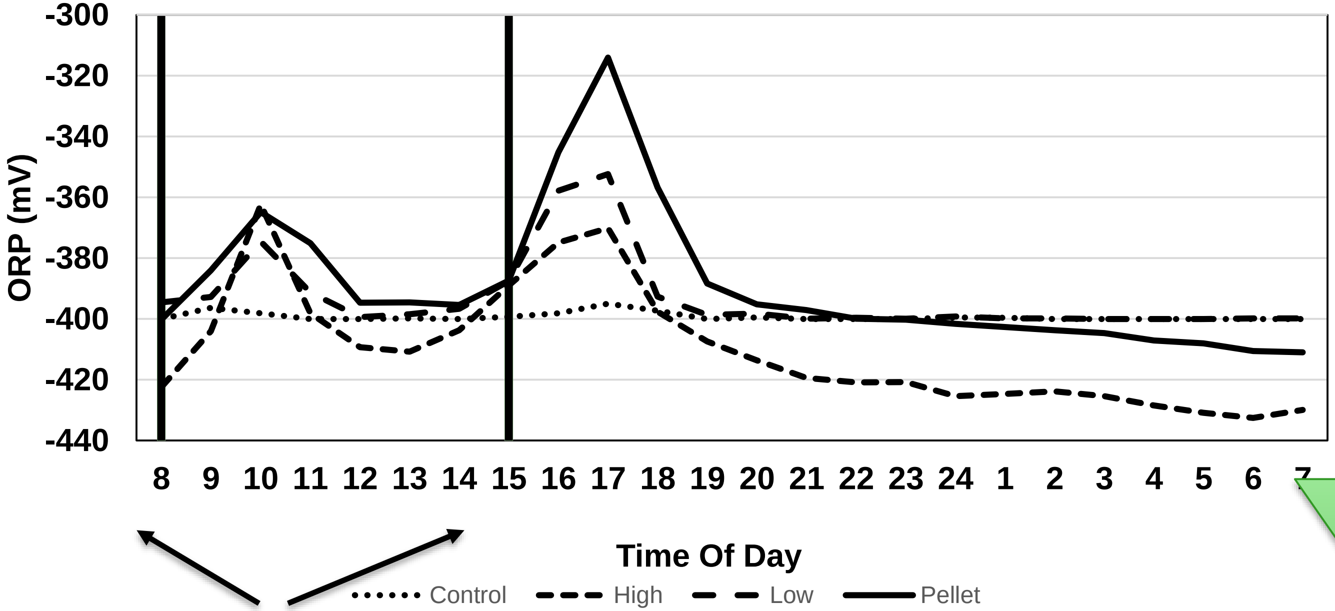
ORP profile over 24h period



Fed 2x/d (AM + PM)

↑ ORP = ↓ CH_4

27% ↓ in CH_4 g/d

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Effect of *RumenGlas* on methane emissions and performance in beef cattle

Preliminary results:

- Compared to unsupplemented control diet:
- **RG (High)** reduced methane (g/d) ↓**30%**
  Feed intake reduced by 14% - possible formulation or palatability issues
- **RG (Low)** reduced methane (g/d) by ↓**18%**
  18% increase in weight gain (ADG)
- **RG PELLET:** reduced methane (g/d) ↓**28%**
  No negative effect on intake and improved weight gain (**18%)**

Advantages : Ease of delivery 2x/d feeding in a pellet

Roskam et al., In Preparation

GlasPort Bio

Current and Future work

- **Dairy grazing feed additive studies – lack of persistency**
  - Effective only for 3 hours
- **Development of new formulations** for extensive/grazing application
- Mechanism of action – VFA and rumen microbiome studies
- Sensory and residue analysis (meat and milk)
- Cost effectiveness (affordability) and life cycle analyses
- Delivery on farm – uptake by farmers will require industry and state incentives
- Incorporation into national inventories (EPA)

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METH-ABATE - Development of novel farm ready technologies to reduce methane emissions from pasture based Irish agricultural systems

- **Feed additives** to mitigate methane emissions – monitoring their effects on animal productivity (cattle and sheep)
  - 3-NOP , seaweeds, oils, oxidising CH_4 inhibitors,
- Encapsulation for **slow release** options at pasture
- **Nutritional and toxicological** composition of meat and milk - to confirm **consumer safety – no residues**
- Teagasc **Life Cycle** (LC) Analysis models
- **Farm level cost effectiveness** will be evaluated - **national farm survey**.

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Summary

- Promising research currently on-going to develop mitigation strategies
  - Feed additives – constant supply in rumen, issue in pasture based systems
  - 3-NOP and oxidising CH_4 inhibitors most promising to date
  - Red seaweed – supply and residue issues
  - Oils – risk reduced DMI, digestibility > 5%
- Slow release options essential for pasture based systems
  - **DSM** developing a slow release option - initial prototypes able to extend methane reduction from feeding time to 6-8hrs with 1 small dose (Muetzel et al., 2019).
  - **Oxidising CH_4 inhibitors:** Slow-release bolus for extensive/pasture-based application
  - Being developed by NUIG and GlasPort Bio (Meth-Abate)
  - Solubility kinetics - active for periods of weeks/months
  - Layered encapsulation to extend release rates

Acknowledgements

Prof Sinead Waters

Prof David Kenny

Prof Vincent O'Flaherty

Dr Maria Hayes

Emily Roskam

Dr Paul Smith

Caroline O'Donnell

Alison Graham

FACCE ERA-GAS
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European Commission
HORIZON 2020

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SEASOLUTIONS

Funding: Irish Department of Agriculture, Food and the Marine (RSF contract no. 2019R479)
Science Foundation Ireland (19/FFP/6746)
EU ERA-NET (SeaSolutions: 696231)
EU Horizon: MASTER (Contract no. 818368)

National University of Ireland, Galway
Ollscoil na hÉireann, Gaillimh

Science Foundation Ireland sfi For what's next

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